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J. R. Kattus, Chairman
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April, 1960

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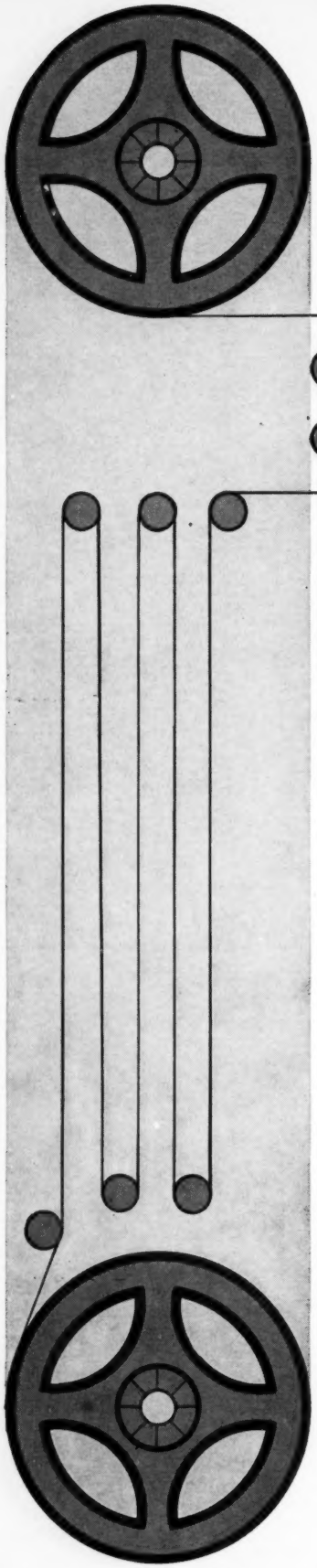
METALS REVIEW

The News Digest Magazine



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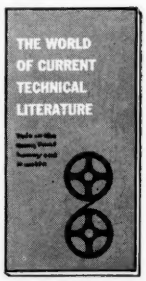

April, 1960 Vol. XXXIII, No. 4

METALS REVIEW

The News Digest Magazine

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J. R. Kattus, Birmingham, Heads Up 1960 Southern Metals Conference

"METALLURGY—THE ROAD AHEAD" is the keynote of the 1960 ASM Southern Metals Conference, to be held Apr. 18, 19 and 20 at the Dinkler-Tutwiler Hotel, Birmingham, Ala.

J. R. Kattus, head of the Metallurgy Division, Southern Research Institute, Birmingham, is chairman of the three-day conference, featuring a well-balanced program of technical sessions of direct interest to ASM members in the South. Kattus states that, while the bulk of the attendance will come from ASM's 13 southeastern district chapters, any interested metals men will be welcomed.

The high caliber of the subject matter and speakers for this year's Southern Metals Conference, he predicts, should be attractive to anyone interested in the production and working of metals.

Delivering the keynote address on the morning of Apr. 18 will be National Treasurer Robert J. Raudebaugh of International Nickel Co. Featured speaker for the Tuesday evening banquet will be Col. J. W. Harrell, Jr., United States Air Force, who will speak on "Your Air Force".

A social hour and buffet are scheduled for Monday evening at the Vestavia Country Club, while a technical tour of Tennessee Coal and Iron Division, Fairfield Steel Works and Tin Mill has been scheduled for the Tuesday afternoon session.

While ASM members are participating in the technical sessions at the hotel, their wives will enjoy a varied program of luncheons and tours of interesting points around Birmingham.

Kattus, chairman of the 1960 Southern Metals Conference, served as chairman of the Birmingham Chapter during the 1954-1955 season. He is also a member of the American Society for Testing Materials, American Foundrymen's Society, National Association of Corrosion Engineers, and AIME.

As head of the Metallurgy Division of the Southern Research Institute, Kattus supervises research projects on cast and wrought steels, nonferrous alloys, cast iron aircraft structural metals and refractory metals.

He is also involved in elevated-temperature properties of metals and graphite, effects of strain rate and holding time on elevated-temperature mechanical properties, salt spray corrosion, thermal shock properties of cast iron and development of cast boron steels.

He has authored a number of published articles, papers and government technical reports, including two articles in *Metal Progress:* "Mechanical Properties of Boron Steels", in April, 1956, and "Investigation of Lockformer Per-

formance of Galvanized Sheet Steel", in December of 1957.

A metallurgical engineering graduate of Purdue University, he held several research positions in industry prior to joining the Southern Research Institute in 1952.

The complete program of technical sessions at the Dinkler-Tutwiler Hotel follows:

SUNDAY, APR. 17

4:00-6:00 p.m.—Lobby
Registration

MONDAY, APR. 18

8:00 a.m.—Lobby
Registration

9:00 a.m.—Terrace Ballroom

Keynote Address, by R. J. Raudebaugh, International Nickel Co., National Treasurer, A.S.M.

Steel, by O. T. Marzke, Vice-President, U. S. Steel Corp.

Cast Ferrous Materials, by H. C. Aufderhaar, Union Carbide Metals Co.

2:00 p.m.—Terrace Ballroom

Light Metals, by G. F. Kappelt, Chief Metallurgist, Bell Aircraft Corp.

Refractory Metals, by Joseph Maltz, Head, High-Temperature Materials Section, Bureau of Naval Weapons

Statistical Design, by John Hromi, Supervising Technologist, Research Laboratory, U. S. Steel Corp.

6:00-7:00 p.m.—Vestavia Country Club
Social Hour

7:00-9:00 p.m.—Vestavia Country Club
Buffet Dinner

TUESDAY, APR. 19

9:00 a.m.—Terrace Ballroom

Vacuum Metallurgy, by J. D. Nisbet, President, Allvac Metals Co.

Nuclear Metallurgy, by D. W. Lillie, Manager, Process Laboratories, General Electric Co.

Metallography, by R. T. Gray, Head, Metallographic Section, Oak Ridge National Laboratory

2:00 p.m.—Fairfield Steel Works and Tin Mill
Technical Tour, Tennessee Coal and Iron Division

6:00-7:00 p.m.—Dinkler-Tutwiler Hotel
Social Hour

7:00-10:00 p.m.—Dinkler-Tutwiler Hotel
Banquet
Speaker: Col. J. W. Harrell, Jr., U.S.A.F.
"Your Air Force"

WEDNESDAY, APR. 20

9:00 a.m.—Terrace Ballroom

Unique Fabricating Methods, by P. C. Rossin, General Manager, Refractomet Division, Universal-Cyclops Steel Corp.

Welding, by A. R. Lytle, Senior Consultant, Linde Co.

Surface Treatment and Corrosion, by C. H. Sample, Supervisor, Electroplating, International Nickel Co.

Houston Day Set for Southwestern Metal Show

EXTENSIVE PLANS HAVE BEEN made by the Houston Chapter A.S.M. to organize a large Houston representation to attend the 2nd Southwestern Metal Congress and Exposition, May 9-13 in Dallas. Other A.S.M. chapters in the Southwest area are making plans for similar representation.

William D. Gilder, Houston chairman, says Tuesday, May 10, has been designated "Houston Day" at the Southwestern Metal Show, and response to this spotlighting of the metal industries in Houston has been gratifying. Already, he reports, nearly 50 chapter members have made plans to attend this important event.

Gilder also announces formation of Houston Chapter Metal Show committees for transportation, exhibit space, technical papers, reservations for attendance, technical and trade publications and local publicity. He expects the five-day metalworking event to be a major factor in attracting new industry to Texas and the entire Southwest.

Equally enthusiastic about preparations for the event in Dallas are the other A.S.M. chapters within a 600-mile radius of the Metal Show city. As a result, Thursday, May 12, will be proclaimed "Southwestern A.S.M. Chapters Day" at the Metal Show, which indicates the tremendous value of the worth-while technical information and ideas exchanged monthly at A.S.M. Chapter meetings in the Southwest.

Plans Completed for Southwest Metal Congress and Exposition

ONLY WEEKS AWAY IS the time when Dallas and Fort Worth will become co-capital cities of the wonderful world of metals.

Always a beehive of metalworking activity, this North Texas area is now accelerating its preparations for the invasion of thousands of metals men, from every part of the Southwest, to the 2nd Southwestern Metal Congress and Exposition, May 9-13.

Never before has a spectacle of such significance to the metal industry been presented in the Southwest. And as time draws short, many last-minute plans are being made to attend and benefit from the highly informative Metal Show.

The multitude of important technical topics to be discussed, described and demonstrated at the five-day metalworking extravaganza, will be firmly rooted in new developments for immediate application in the metalworking plants of the Southwest and the entire United States.

Allan Ray Putnam, managing director of the sponsoring American Society for Metals, is confident of the success of the event after visiting the area and comprehensively reviewing the program of technical sessions and roster of exhibits.

The Southwestern Metal Show will be in Texas State Fair Park, where its first appearance was made two years ago. Technical sessions of the Metal Congress will take place in the A.S.M. headquarters hotel, the Sheraton-Dallas.

A comprehensive, four-day program of technical sessions, involving six major topics of immediate and practical application, has been formulated for the Southwestern Metal Congress.

Metal Congress session topics are "Composite Materials for High-Temperature Application", "Steels for High Load Applications", "New Frontiers in Metal Processing", "Failure Analysis", "Testing at High Temperatures—Over 2000°F.", and "Castings for High-Temperature and Corrosive Service".

Chosen to appear in these sessions are authoritative metals research engineers and educators from universities, military centers and plant laboratories from many parts of the United States.

New suggestions to overcome difficult metalworking problems—particularly those in the aircraft, missile, space vehicle, rocket, electronics, instrument, chemical and petroleum industries—will be available to all who attend.

In conjunction with the A.S.M. Metal Congress, the Society for Nondestructive Testing will hold three days of technical sessions, beginning May 9, in the Baker Hotel.

Heavy attendance at the Exposition and Congress is expected from Texas' rapidly expanding and vital metal fabrication centers. Additional influx is anticipated from Oklahoma, Louisiana, Alabama, Missouri, Kansas, New Mexico, Colorado and Mexico. Many other sections of the nation are due to be represented by metals engineers and plant executives.

A.S.M. chapter chairmen in Houston, Tulsa, Birmingham, New Orleans, St. Louis, Kansas City, Wichita, Los Alamos, Albuquerque and Denver are organizing groups of their members and members of other prominent technical societies to attend the Texas event.

Host committee of the Southwestern Metal Show is headed by Stephen Maszy, vice-president, Perzy Heat Treat Inc., Arlington, Tex., chairman of North Texas Chapter (Dallas-Ft. Worth area).

Despite a heavy demand for exhibit space in the Exposition, a few choice locations for exhibitors remain available. Information on these may be obtained from Chester L. Wells, exposition manager, at A.S.M. Headquarters, Metals Park, Novelty, Ohio. After Apr. 25, Wells can be contacted at his office at Texas State Fair Park.

No charge will be made for attendance at A.S.M. Metal Congress sessions. Thousands of admission-invitations for the Exposition are being distributed to cooperating technical society members and customers of exhibitors. Persons who have not received admission-invitations may register for all five days at the Metal Show for the nominal charge of $1.

Committee Project Completed on Carbon and Low-Alloy Steels

COMPLETION OF a major committee project on Carbon and Low-Alloy Steels has been announced by A.S.M. management. Involving 243 members and friends of the Society, each a top authority in his field, the project truly exemplifies the basic aim of the A.S.M.—free exchange of ideas and information for the benefit of all.

The project has been organized in three major sections: Steel Products and Properties, Selection of Steel for Engineering Properties, and Selection for Processing and Economy. Twenty-five separate reports comprise the three sections, largely compiled by 18 technical committees. The 243 participants come from 181 metalworking plants in the important industrial centers of the nation.

The section on *Steel Products and Properties* includes articles on hot finished steel bars, cold finished steel bars, steel tubular products, low-carbon steel sheet, high-strength low-alloy steels, hardenable steels, steel castings, forgings, wire, bolts and springs.

Selection for Engineering Properties deals with yield strength at minimum cost, hardenability, fatigue resistance, notch toughness, wear resistance and corrosion service.

Selection for Processing and Economy involves plant standardization of grades and sizes, selection for over-all economy of manufacture, for economy of machining, minimum quench cracking, formability, deep drawing, porcelain enameling and welding.

Chairmen of the 18 committees on Carbon and Low-Alloy Steels are: Emil C. Blocks, research metallurgist, Ekco Products Co.; A. L. Boegehold, past president, American Society for Metals; W. C. Cadwell, assistant chief engineer, Caterpillar Tractor Co.; Charles A. Davis, materials engineer, Deere & Co.; J. A. Erickson, chief metallurgist, Euclid Division, General Motors Corp.; and Maurice F. Garwood, chief materials engineer for the Chrysler Corporation.

J. D. Graham, chief materials engineer, International Harvester Co.; Joseph Gurski, manager, Chemical and Metallurgical Laboratory, Manufacturing Services, Ford Motor Co.; Raymond H. Hays, plant metallurgist, Caterpillar Tractor Co.; Walter E. Jominy, past president, American Society for Metals; Ralph W. E. Leiter, chief metallurgist, The Budd Co.; and William A. Pennington, professor of metallurgy, University of Maryland.

G. C. Riegel, retired chief metallurgist, Caterpillar Tractor Co.; W. C. Schulte, chief metallurgist, Propeller Division, Curtiss-Wright Corp.; Howard Tillson, Ladish Co.; D. J. Wright, quality control manager, Caterpillar Tractor Co.; J. F. Wallace, associate professor of metallurgical engineering, Case Institute of Technology; and C. Emmett Zwahl, retired engineering metallurgist, Chevrolet Division, General Motors Corp.

The project on Carbon and Low-Alloy Steels will be published later this year as one of four major sections in the new edition of the A.S.M. Metals Handbook, Vol. I, "Properties and Selection of Metals".

M.E.I. to Hold Short Course

During the week of June 6, M.E.I. is planning to offer Course No. 10, "Heat Treatment of Steel", at A.S.M. Headquarters. Enrollment will be limited to about 30 persons. Housing facilities are available for a limited number of students on a "first-come, first-served" basis.

The course, to be taught by M.E.I. staff members, will cover basic principles and will emphasize the fundamental rather than the "how to do it" aspects of proper heat treatment.

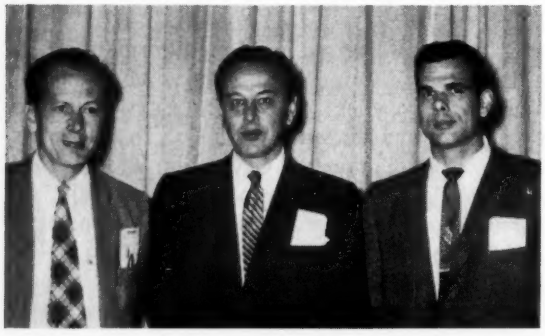
For further information write to Metals Engineering Institute, Metals Park, Novelty, Ohio.

Vacuum-Melting of High-Temperature Alloys

AT A RECENT MEETING OF the Santa Clara Valley Chapter, "Vacuum Production Melting of High-Temperature Alloys", a description of the production vacuum melting process and solutions to the problems encountered at Kelsey-Hayes, was given by Falih N. Damara, president of the company. The melting process used is a semicontinuous one which can produce ingots weighing up to two tons. The vacuum is held to about three microns.

One of the important features of the induction vacuum system is the use of two frequencies. A 30-cycles per sec. frequency is used as a stirring device and there appears to be no appreciable heating at this frequency. The heating frequency is 900-cycles per sec. At this frequency the agitation is small, the heating effects are large.

R. Wayne Parcel, F. N. Darmara and Malcom Davis Are Shown at a Meeting of Santa Clara Valley.



Dr. Damara reviewed the general concepts of distillation and described the method of removal of elements by the formation of volatile compounds, principally covering the removal of oxygen by the formation of compounds with carbon. Another important concept brought out was that the additions of aluminum and titanium to the nickel-base alloy must be made after the oxygen is removed. Since the high-temperature strength of these alloys depends on the formation of Ni-Al-Ti compounds, the Al and Ti must be free and not bound by oxygen compounds.

The speaker then compared the properties of a typical high-temperature alloy melted in air and one melted under vacuum. The alloy Waspalloy melted in vacuum displayed a stress-rupture life about ten times that of an alloy melted in air. *(Reported by William Nix for Santa Clara.)*

Reviews Developments in the Cold Extrusion Process

DEVELOPMENTS IN THE COLD EXTRUSION PROCESS during the past few years have created widespread interest in the metalworking field. Cold extrusion provides such advantages as being applicable to less-expensive base metals, results in scrap savings, reduces or even eliminates subsequent machining operations, reduces labor costs by being applicable to high production methods, provides improved surface finish to close tolerances and results in excellent physical and mechanical properties. These statements were offered at a Dayton meeting by R. W. Gardner, Varson Allsteel Press Co., who used a series of slides to illustrate these various advantages as compared to other processing methods.

Cold extrusion is the forming, molding or shaping of parts in a die with application of sufficient pressure to create plastic flow of the billet. The basic cold extrusion process breaks down into several separate types, such as backward, forward and combination extrusion. While cold extrusion processes offer various advantages, they are not cure-alls and are applicable only for designs that do not require many secondary operations. It is a process that should have considerable volume to be most economical.

The design of dies is a vital part of the success of cold extrusion operations. Deflection problems cause most concern since they can rapidly ruin costly tools and dies. Much attention must be given to correct tooling that will withstand the tremendous pressures involved. Information on basic tooling needed for the three cold extrusion methods was provided to show the wide application of the process. When done correctly, cold extrusion work can also be adapted to automatic feeding which provides further advantage. Cold extrusion can be accomplished on hydraulic or mechanical presses. The economics of each must be considered for each application.

The correct application in understanding lubricants is necessary for cold extrusion work. Clients generally do not use oil for lubrication purposes but resort to phosphate coatings from dip systems. This operation is normally a series of treatments to remove grease, scale and other foreign matter and to etch the surface prior to applying the lubricant.

The properties of the material being extruded influence the success of the operation. Hot rolled alloys are now being applied to cold extrusion

(Continued on p. 21)

Shear Spinning—A new technique in metal forming, as reported at the recent Golden Gate Metals Conference, is known as shear spinning. Experiments are underway to determine suitability of the process to the production of solid fuel rocket cases. A thick blank of the metal to be formed is made to flow over a mandrel in such a way that the blank thickness is reduced and the length extended. Deformation is in shear rather than tension or compression. In making a cone, workers have achieved a 45% reduction in thickness of the metal.

New Missile Steel — Modification of AISI 4100 type steel by the addition of cobalt has provided a substantial increase in yield strength. Standard 4100 steel develops about 210,000 psi. compared to 250,000 psi. for the steel with cobalt added. The new alloy was developed at Mellon Institute.

High-Temperature Brazed Joints—Researchers at Armour Institute are developing brazing alloys containing temperature depressants. The alloys permit joining stainless steel at a relatively low temperature during which the additive in the brazing alloy volatilizes, leaving joints of high remelt temperature.

Resurfacing by Chemicals — A new chemical treatment is being used to eliminate pits and scale from the surface of hot rolled stainless steel. The treatment is capable of improving the steel surface to the point where it can meet aircraft quality standards.

High-Temperature Columbium Alloy — A new columbium alloy, known as Cb-65, is said to have an ultimate tensile strength of 37,000 psi. at 1800° F. The alloy is designed to maintain low neutron cross section and to provide increased mechanical strength and oxidation resistance over similar properties in pure columbium. The new alloy can be extruded and forged.

Cadmium Vapor Plating—Commercial application is now being made of a process in which thick films of cadmium are deposited on steel parts by a vapor-vacuum process. Vacuum coating is said to eliminate the problem of hydrogen pick-up in cadmium plated parts. Early uses of the process are being made in protecting aircraft hardware against corrosion.

French Metallurgical Meeting—The annual Autumn Meeting of the French Society of Metallurgy will be held at the Maison de la Chimie, Paris, Oct. 17-21, 1960. The theme of the meeting will be "Heat Treatment of Metals and Alloys". Metallurgists seeking to present papers having to do with this theme should send the title and a résumé of 500-1000 words, in duplicate, to the secretary of the Society before July 1, 1960. While the résumés can be in French, English or German, oral presentations at the meeting must be made in French. The final program for the meeting will be distributed in Sept. 1960. For further information write to: Secretariat, Societe Francaise de Metallurgie, 25, Rue de Clichy, Paris (9), France.

Strong Aluminum Honeycomb—A new aluminum honeycomb emerging from the laboratories is 15 to 30% stronger than previously available aluminum alloy honeycombs. Known as 5056 honeycomb, the material will be available in $\frac{1}{8}$ to $\frac{3}{8}$ in. cell diameters, 0.001 and 0.002 in. gage thicknesses and in sizes up to 28 by 96 in.

Refractory Material Readily Fabricated — A tough, fibrous refractory material is now available for fabrication into various shapes to be used where extreme high temperatures are involved. The material is reported to be capable of withstanding temperatures of more than 3000° F. for several hours. Early indicated uses include heavy-duty exhaust systems and the transport of metals in the liquid state.

Two Refractory Metals Conferences—Two conferences on refractory metals are scheduled for May, one in Detroit, the other in Santa Monica, Calif. The Santa Monica Conference, arranged by the Los Angeles Chapter ASM is scheduled for May 12 and 13. Special emphasis is being placed on the use of these metals in aircraft and missiles. The Detroit Conference, to be presented by The Metallurgical Society of AIME, will be staged May 25 and 26. A special feature of this program will be a panel-type discussion on "Comparative Status of Refractory Metals for Engineering Applications".

Materials for Use in Rockets and Missiles

THE OPERATION OF solid and liquid propellant motors, and their structure, from the point-of-view of materials used, were covered in a talk on "Rockets and Missiles" by H. P. Tardif, Canadian Armament Research and Development Establishment, at a meeting in Ontario.

The main areas for materials utilization are the superstructure, combustion chamber, nozzle and nose cone. Superstructure materials are predominantly the light metals aluminum and magnesium which assure a favorable ratio of propellant mass to total mass at launching. Alloy and stainless steel are extensively used in critical areas where lightness must be sacrificed to such properties as high strength and heat resistance. Beryllium shows excellent possibilities because of its good thermal properties and strength-to-weight ratio and will be used more extensively as its difficult technology is mastered.

Case-bonded solid propellant systems possess a distinct advantage with respect to combustion chamber design since the propellant serves to insulate the missile shell from the combustion area. In liquid propellant systems, the combustion rate can be controlled via the injection rate, whereas the rates in solid systems depend on the exposed surface area of propellant and cannot be controlled easily.

The materials problems of the nose cones and nozzles are quite similar since they involve the removal of heat from the surface. In the case of nose cones, designed to provide thermal protection for the payload, the heat sink and the ablation methods are used. In the first method, surface melting is prevented by providing a sufficient mass of a high melting metal with high thermal diffusivity. Copper is used in the Atlas and Titan nose cones, whereas the heat shield for the first U.S. manned satellite will probably be beryllium. Heat sink systems are limited to low re-entry velocities and therefore are used with blunt nose configurations. In the ablation method, heat is removed via the gases evolved in chemical reactions or by vaporization and sublimation.

In the Canadian program, three case-bonded, solid propellant rocket engines have been developed to obtain a test vehicle for studying propellants, to permit upper atmosphere research and to form a group of experts in this field. *(Reported by J. S. Kirkaldy for Ontario.)*

At Left Is the Speaker, H. P. Tardif, Canadian Armament Research and Development; Right, Ontario Chairman H. G. Warrington.

Epoxy Resins and Their Applications

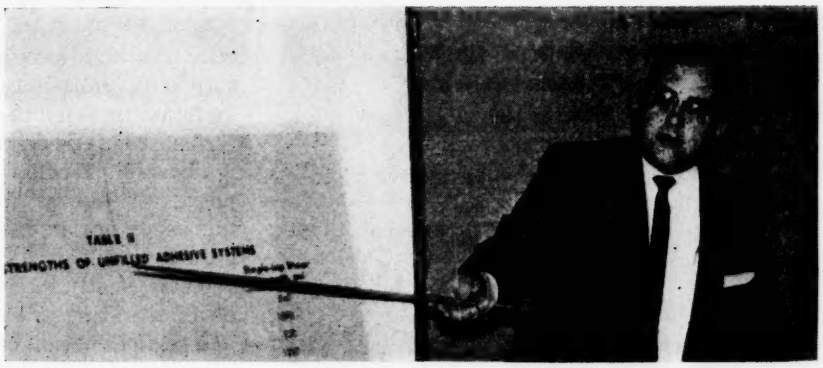
CONSERVATIVE ESTIMATES for the future indicate that 80 to 90,000,000 lb. of epoxy resin will be consumed yearly by the early 1960's, according to David A. Bisson, technical representative, Union Carbide Plastics Co., Division of Union Carbide Corp., who gave a talk on "Epoxy Resins and Their Applications" at Utah.

Epoxy resins are relative newcomers to the plastic field. Their properties include excellent chemical resistance, excellent electrical performance, favorable mechanical strengths, high adhesive strengths, low shrinkage, room-temperature cure and toughness.

Other properties epoxy resins exhibit and possible applications are in the production of tools and dies which require a strong, nonshrinking, relatively light-weight resin which can be set at or near room temperature without the use of strong acids, or in precision castings which require good mechanical properties and low shrinkage during cure.

The ability to cure at relatively low temperatures, plus such properties as good adhesion, toughness and good electrical performance, have insured the success of epoxies in the potting, encapsulating, embedding and reggedizing of electrical and electronic components.

Mr. Bisson explained an epoxy resin as being



David A. Bisson, Union Carbide Plastics Co., Illustrates a Point Made in His Lecture at Utah.

characterized by having reactive epoxide groups, also called Oxirane rings, in the resin structure. These groups, along with hydroxyl groups present, are the focal point for crosslinking or curing reactions. The most widely used epoxy resins are glycidyl ethers of diphenols.

Epoxy resins are available in both liquid or solid form. Liquid epoxy resins may be cured to a hard, infusible state by a variety of compounds containing active hydrogen groups or by a catalyzed self-polymerization. Because numerous curing agents are available for the epoxies it is possible to obtain a desired combination of properties by appropriate agent selection.

Mr. Bisson defined an adhesive as a material which can bond two other materials together by adhering strongly to the surfaces of both. He classified adhesives by adhesive mechanisms, and subdivided them into solvent activated adhesives, heat sealing adhesives, chemically reactive adhesives and pressure sensitive adhesives.

The epoxy resins fall into the category of chemically reactive adhesives. Whatever the adhesive classification, the mechanism of adhesion is the same. It is believed that chemical or physical forces, rather than mechanical, play the major role in adhesion.

Because of the inherent properties of the resins, epoxies make outstanding adhesives. The first requirement for a good bond is complete wetting of the surface. Epoxies, because of their polar nature, will wet a variety of different materials, including plastics, wood, metals, glass, ceramics and various rubbers. This adhesive characteristic, plus chemical and abrasion resistance, particularly suit the epoxy resins for coating applications.

Mr. Bisson gave as examples for the practical uses of epoxy resins the structural bonding of aircraft, thermal insulation for refrigeration, decorative applications, repair of electrical and electronic equipment, concrete applications and repairs, production of tools, dies and precision casting and coatings.

Some of the limitations of the material Mr. Bisson outlined were the length of time required for full strength to develop and limited heat resistance above 500° F. for an extended period of time. *(Reported by L. Jacobson for Utah.)*

Cerrotechnics–the Low-Melting Metals

"CERROTECHNICS" WAS DEFINED as the "how and why" information about the low-melting metals, specifically the cerro-alloys, by Robert S. Darnell, assistant manager, Alloy Dept., Cerro de Pasco Sales Corp., at a meeting in Albuquerque. Mr. Darnell illustrated his talk with slides showing the many ways in which the low-melting metals may be used.

Bismuth is a coarsely crystalline metal which is quite dense. The metal expands upon solidification 3.3% of its volume. This peculiar property of bismuth is carried over into most of its alloys.

Before 1930 the bismuth alloys that melted at low temperature were little more than interesting curiosities. One or two industrial applications had been developed, mainly in the field of sprinkler-system plugs and fire-alarm devices. Since that time some 1000 of these alloys have been tested and charted. Known as "eutectic" metals, the principal bismuth alloys, numbering about 15, are used in over 60 major applications. They have melting temperatures as low as 117° F. and melting ranges up to 440° F.

All bismuth alloys are poor conductors; conductivity is approximately 3% that of copper. The peculiar characteristics of these alloys, particularly their low-melting points and absence of shrinkage upon solidification, are responsible for their wide range of usefulness.

Looking at the Space Age From A Metallurgist's Point-of-View

THE CHALLENGE TO engineering skills and the spirit of accomplishment were underscored as primary factors in "A Metallurgist's View of the Space Age", reported by Wolfgang H. Steurer, Convair, at a meeting in San Diego.

Dr. Steurer gave a historical review of rocketry, and displayed old drawings of vehicles for space flight conceived before the turn of the century, noting their striking similarity to "new" ideas of today. Despite the early interest in space flight, however, engineering efforts to date have been concentrated primarily on the atmospheric phases of flight. In particular, aerodynamic heating of rocket nose cones has been a problem for materials engineers and metallurgists.

Short-time studies of structural steels at elevated temperatures indicate that optimum heat treatments can be selected to retard annealing rate and thus provide moderate mechanical properties for the short duration of atmospheric flight. For instrumented or manned flight, an insulating or heat dissipating system is required to keep compartment temperatures at a reasonable level. Dr. Steurer described many systems which have been developed, including heat sinks, transpiration and ablation systems.

Ninety-five miles beyond the earth's surface the problems of space flight transcend the problems of atmospheric flight. Aerodynamic heating decreases rapidly (regardless of speed) and solar heating becomes predominant. Externally applied coatings having a calculated ratio to absorptivity emissivity have been successful in maintaining satellite compartments within a prescribed 20° temperature range.

The high vacuum beyond the earth's atmosphere presents further unusual problems, including vapor pressures of materials at 10-10 mm., diffusion of gas through the skin of a space vehicle, greatly increased friction of mechanical parts operating in vacuum and effects of cosmic and solar radiation on sealants. Micrometeorites, however, are not expected to be troublesome as their high collision velocities will cause most of them to vaporize and dissipate.

Dr. Steurer concluded with thought-provoking statements concerning the possible effect of rocket research on world relations. He contended that technological competition between nations for conquest of space can replace the historical competition of warfare. The winner in this competition will be superior, but not victorious. If we are to be the superior nation we must, without delay, coordinate our efforts and formulate long-range plans. Planning must include ways and means for placing greater emphasis on scientific accomplishments, reconcile the differences between government and private participation, encourage quality rather than quantity of engineering graduates, make higher education available to all potential engineers, promote original thinking, and, above all, combat and overcome national passivity. To encourage us and give us impetus, the concept of space competition offers three incentives: a national ideology, a replacement for war, and the challenge of the unknown. *(Reported by F. L. Brown for San Diego.)*

Reviews Properties of Graphitic Steels at Western Ontario Chapter

Owen A. Pfouts, Toolsteel Metallurgist, Steel & Tube Div., Timken Roller Bearing Co., Spoke on "Graphitic Steels" at a Western Ontario Meeting. Shown are, from left: Frank J. Miller, Steel Master Tool Co., Ltd.; Mr. Pfouts; John Kennedy, Bendix-Eclipse of Canada Ltd.; and Lloyd White, General Motors of Canada Ltd.

Weldable High-Strength Steel Reviewed

C. L. ALTENBURGER, technical assistant to the president, Great Lakes Steel Corp., spoke on "Weldable High-Strength Steels" at Peoria. He pointed out that high-strength steels in general were originated in the middle 1930's. The highest quality of high-strength steels at that time were from fully killed steels. A few semi killed steels were developed which were lower in price but usually did not have the quality of killed steels.

In the past 1½ years there has been considerable development of a high-strength semikilled steel by adding columbium up to 216% per ingot ton. The addition of columbium has increased the yield strength of steel containing 0.15% carbon and 0.50-1.50% manganese from 33,000 to over 60,000 psi. Even though the steels are not full hardening materials, heat treatment can enormously improve the properties in spite of the fact that columbium decreases the hardenability up to 0.07%.

Mr. Altenburger illustrated the strength characteristics and other physical properties of columbium-treated steels. One of the important aspects of these steels is that weldability is enhanced. The probable reason for this is that columbium has characteristics similar to vanadium, titanium and aluminum, which are powerful nitriders and grain refiners.

In considering the economics of a weldable high-strength steel, a weight savings must be possible to justify the higher cost of such a material. By using a properly designed section the maximum advantage of a columbium-treated steel can be realized. The discussion was concluded with a question and answer period. *(Reported by W. T. Bott for Peoria.)*

J. R. Sloan, Technical Chairman, C. L. Altenburger, Speaker, and T. W. Peck, Chairman, at a Meeting in Peoria.

Past President Lorig Guest at Jacksonville University

Immediate Past President Clarence H. Lorig, Is Shown at a Meeting Held at Jacksonville University, Where He Spoke on "Materials for the Space Age". From left are: Frank F. Worley, Stephen Bowes, W. L. Baker, Dean Helen Merrill, Dr. Lorig, Ted DuMond, Dean Norton, Bernard Boisvert, and Douglas L. King.

Use of Magnesium and Lithium in the Steel Industry

EVER SINCE NICKEL WAS FOUND to be effective in producing a stable austenitic structure in chromium steels, metallurgists have been busy investigating ways and means of eliminating or at least substantially reducing the amount of nickel required for the production of 18-8 type stainless steels, according to E. M. Kipp, Foote Mineral Co., who spoke in Ontario.

Carbon, nitrogen, manganese and copper promote austenitic structures in chromium steels and individually or collectively can replace much or all of the nickel in the production of commercially useful stainless steels. Several chromium-manganese steels were actually in commercial production in the U.S. by the late 1930's and early 1940's. Work by Union Carbide and Carbon Co., and that of other laboratories, indicated that to produce an austenitic steel using only chromium and manganese, the chromium content cannot exceed 13%. At this level of chromium, 13% or more of manganese is required. If more chromium or less manganese are used, a fully austenitic structure cannot be maintained.

Austenitic alloys containing more than 13% Cr and less than 13% Mn can be made by using reduced amounts of nickel and from 0.1 to 0.15% N. Fully annealed steels containing 3 to 6% Mn and 5% Ni were developed which were generally equal in ductility to the 18-8 chromium-nickel steels. Investigations also indicated that, as a general guide, nickel is about twice as effective as manganese in promoting a stable austenitic structure; that 0.2% N is approximately equivalent to 4% Ni.

By 1954 a Cr-Mn-Ni grade, TRC, was in commercial production by the Budd Co., which used it extensively in railway cars and trailer bodies. TRC had a nominal composition of 15% Cr, 16½% Mn, 1% Ni, 0.15% N, 0.10% C, and was generally referred to as 16-16-1 alloy. It is a faster work hardening alloy than 18-8 steel, and can be fabricated by the procedures useful for Types 301 or 302 stainless. Corrosion properties under mild to moderate conditions were approximately equal to 18-8 though somewhat inferior to 18-8 in applications of a highly corrosive character.

A 17%, 6 Mn, 4%, 0.15% N, 0.10% C steel was successfully developed for limited commercial production in the early 1940's with mechanical properties and corrosion resistance generally comparable to those of a 17-7 Cr-Ni alloy.

Another example of the successful use of manganese as a replacement for a considerable percentage of the nickel otherwise required is a composition generally known as 16-25-6. In addition to the 16% Cr and 25% Ni, it also contained 6% Mo. It was developed primarily to eliminate the use of the highly strategic metals cobalt, columbium and tungsten. However, it still required 25% Ni. Through the use of manganese as a partial substitute for nickel it was shown that 6% Mn could replace 10% of the nickel and a new alloy, 16-15-6-6, was produced. With the exception of inferior physical properties at temperatures above 1400-1600° F., the modified alloy performed in a completely satisfactory way and was fully equivalent to the 16-25-6 alloy.

Another example of the possibilities inherent in the use of austenite-forming elements to replace varying amounts of nickel was the use of manganese and nitrogen to completely replace nickel. U. S. Steel Corp. developed a composition known as Tenelon, which was nickel-free, austenitic and comparable to conventional austenitic steels in hot and cold working properties. Furthermore, it is superior to Type 301 stainless steel in tensile and yield properties. Corrosion resistance is not as good as 18-8 or 200 and 300 series stainless steels, though generally comparable to Type 430 and 16% Cr, 1% Ni, 17% Mn steels.

Currently the 200 series steels are receiving the greatest commercial acceptance. They were first recognized as a new standard class of alloys in 1955, when production was at a level of approximately 2000 tons, which increased to 25,000 tons by 1957. Typical compositions are: (201) 17% Cr, 4½% Ni, 6½% Mn, 0.15% C, and (202) 18% Cr, 5% Ni, 8½% Mn, and 0.15% C.

E. M. Kipp, Who Spoke at a Meeting in Ontario, Is Shown With the Chairman, H. G. Warrington.

Additional field and laboratory data have established that the 200 series steels, in which substitute amounts of manganese are used to replace considerable percentages of nickel, are generally fully comparable to the steels for which they were originally developed as substitutes. It has been estimated that from 75-90% of the uses of 18-8 and Types 301 and 302 stainless can be satisfactorily filled with the 200 type.

The use of manganese and other austenite-promoting elements has not, as yet, eliminated the use or value of nickel. Unique over-all results are obtained with nickel even when in combination with austenite formers for chromium steels such as manganese, copper, nitrogen, carbon, etc. There is much to be done yet on a research basis in exploring the various permutations and combinations of austenite formers other than nickel in combination with chromium and other potential alloying elements. Manganese has played a significant role in the production of useful stainless steel alloys of lesser nickel content. With the increasing availability of high-purity electrolytic manganese, it will be possible to more effectively carry out research and development studies on the properties and advantages of manganese as a steel alloying element.

The usefulness of manganese as an alloying element for the production of steel alloys is by no means limited to its role as an austenite former for the chromium-type stainless steels. Steel technologists have long been interested in the possibilities of aluminum-iron alloys for production of light-weight steels combining resistance to oxidation and corrosion of aluminum. Interest in the possibility of replacing both chromium and nickel by aluminum is also warranted because of the plentiful supplies of aluminum in contrast to chromium and nickel, particularly in times of war.

Commenting on the use of manganese and aluminum, one of the most interesting of a group of such alloys is one comprising 10% Al, 35% Mn and 0.76% C. Among the most interesting properties of this alloy is its strain-aging characteristics. Its oxidation resistance properties are inferior to those of the chromium-nickel stainless and the aluminum-iron alloys, but they are adequate for selected applications up to temperatures of 1500° F. Ductility at room temperatures approximates that of 18-8 alloys. Although this alloy leaves something to be desired, it nevertheless exemplifies the versatility and probable usefulness of manganese as an alloying element for many types of steel.

The metallurgy of lithium in steel has barely been scratched. Until the impact of atomic energy, there were no important dependable commercial sources of lithium compounds at realistic costs. A great deal of the literature on lithium and its compounds is incomplete and results questionable on the basis of the relatively impure lithium compounds which were used in early investigations. The unique chemical and physical properties of lithium compounds are not thoroughly appreciated, and misleading concepts have originated in the tendency of many research people to regard lithium as essentially similar to other alkali elements. Actually, in many important instances the properties of lithium cannot be forecast from the other elements of the first period, or any other period for that matter. At other times it is more like elements of the second and third periods rather than some of those elements themselves.

The major interest in lithium is as an addition agent to refine and purify steel melts. Lithium metal in small amounts is capable of removing hydrogen, oxygen, sulphur and certain other im-

(*Continued on p.* 21)

Demonstrates Foundry Talk With Tour of Ford Facilities

"Foundry Methods" Were Reviewed by John Perkins, Manager, Ford Motor Co. Foundry, at a Western Ontario Meeting. Shown are, from left: S. Millinoff, general foreman of the heat treat department, Mr. Perkins, and G. Fellows, superintendent of the foundry.

Makes Observations of Iron and Steel Tour of Russia

J. H. STRASSBURGER, vice-president, research and development, National Steel Corp., gave a talk on "Iron and Steelmaking in Soviet Russia" before the Upper Ohio Valley Chapter.

The speaker reported on his 1958 visit to Russia when he was a member of an industrial group representing the U.S. and, in cooperation with the Soviet government, had the opportunity of seeing the Russian iron and steel industry.

The four steel plants visited by Mr. Strassburger were reported to be well run, modern and productive. Production in the U.S.S.R. is stressed more than in the U.S. The incentive system is used throughout the entire iron and steel industry, with 33⅓% of the workers' take-home pay made up from incentive wages.

Steel is "king" in Russia, and with the great manpower shortage, women workers are quite common throughout the heavy industries. The Russian worker is indoctrinated at an early age into materialistic worship and, therefore, is dedicated to production. Graphs depicting yearly iron and steel producing rates of past years and expected yield for the coming year were seen everywhere.

The Russian steel industry employs the finest in blast furnace practice, including self-fluxing sinters, high blast temperatures, high top pressures, oxygen and humidity control but, as Mr. Strassburger emphasized, they have adopted all western practices and have contributed very little improvements of their own to the industry.

While social facilities in Russia are limited and substandard compared to those in America, natural resources are unlimited. But, in spite of a definite shortage of finished steel available for the increasing demand, the Soviet long-range expansion program and economic philosophy make them a definite threat to the western world. *(Reported by R. L. LeVaughn.)*

Using Nuclear Reactors as Tools for Research

ALTHOUGH THE CONSTRUCTION OF nuclear reactors poses many materials problems to metallurgists, D. S. Billington, director of the Solid State Physics Division, Oak Ridge National Laboratory, pointed out in a talk at Oak Ridge that nuclear reactors may also serve as very useful research tools because of their vast supply of neutrons. The use of neutrons for neutron diffraction, activation analyses and preparation of tracers has been demonstrated. Other phenomena associated with radiation damage were discussed, and the potentialities of these phenomena for studying metals were pointed out.

Neutron diffraction is distinctly different from X-ray diffraction in that the neutron scattering power of the nucleus varies at random for different elements, while the X-ray scattering power increases with the atomic number. Neutron diffraction has been used successfully in studying ordering in a 50% Fe-50% Co alloy. Superlattice lines in this system were too weak for detection by standard X-ray techniques. Reasonable advances have also been made in locating the position of hydrogen in the solium hydride structure by neutron diffraction. Since neutrons have a magnetic moment, neutron diffraction can also be used for studying the magnetic structure of the nucleus of metals.

Several uses of tracer materials, ranging from detecting engine wear to use in diffusion experiments were pointed out. The broad range of half

Upper Ohio Valley Chapter Members Who Heard J. H. Strassburger, National Steel Corp., Speak on His Trip to Russia, Included, From Left: Phil Barr and Hal Kessler, Chairman, Both From Titanium Metals Corp. of America, and Julius Strassburger, Speaker, Ivor Campbell, Louis Beale, From National Steel Corp., and Frank Norris, Wheeling Steel Corp.

National Trustee M. A. Scheil Discusses Metal Failures at Meeting of Tri-City Chapter

National Officers' Night Meeting of the Tri-City Chapter Featured a Talk on "Metal Failures" by Merrill A. Scheil, National Trustee A.S.M. Shown are, from left: Jack Peck, vice-chairman; Mr. Scheil; and John Hatch, chairman.

lives which different tracer materials possess make them useful for many purposes.

The concept of radiation damage due to nuclear bombardment was discussed. Fast neutrons have sufficient energy to knock atoms from the lattice of a metal and they also introduce impurities through transmutations. Several examples of the effects of these processes on the properties of certain materials were described. The yield stress of a copper single crystal was increased as the radiation exposure was increased. Radiation exposure was observed to raise the impact transition temperature in a pressure vessel steel and reduce the amount of plastic deformation in a low-carbon steel. Radiation exposure of a high-purity copper single crystals at 20° K. was observed to lower the internal friction of the material and raise the modulus of elasticity. The rate of formation of precipitate in a Ni-Be alloy was increased by irradiation.

Although these phenomena are currently considered problematic in many respects, they point out at least three ways in which radiation damage can be used as a research tool. The effect of vacancies and interstitials resulting from neutron bombardment on mechanical properties is similar to that brought about by alloying. Hence, the equivalent of different concentrations of alloying elements can be assimilated on the same specimens by different radiation treatments and subsequent annealing. Actual alloying can be brought about through transmutation and the alloying element can be added, one atom at a time, by proper control of the radiation dosage. The accelerating effect which irradiation has on diffusion processes makes it possible to study solid state equilibria at room temperature where the approach to equilibrium under ordinary conditions makes the time requirements of such experiments prohibitive. *(Reported by H. E. McCoy for Oak Ridge.)*

Simplified Electron Metallography of Steel

"SIMPLIFIED ELECTRON METALLOGRAPHY OF STEEL" was reviewed by George E. Pellissier, Applied Research Laboratory, U.S. Steel Corp., at a meeting of the Chicago Chapter.

Mr. Pellissier reviewed the advances that have been made in electron microscope instrumentation. One notable comment was that the resolving power of the electron microscope has been improved from 50 Å to 10 Å during the past 20 years. The availability of the selected-area diffraction attachment and other analytical accessories on the more modern equipment permits positive identification of finely divided phases in steels and other alloys.

The extremely high magnifications, available only with the electron microscope, are required to resolve the various fine microstructures that exist in today's complex, high-strength alloy and stainless steels. Most of these structures are so fine that they are beyond the limit of resolution of the light microscope. Investigation of these microstructures and their relationships to mechanical properties are essential in developing superior new steels.

Replica techniques have been simplified and refined to the point where they can be used routinely in steel development and as a means of production control, and metallographic polishing and etching techniques have been improved to be adequate for electron metallography of most steels. Electropolishing has been of great assistance in specimen preparation. However, the major limitation to the more wide-spread application of the electron microscope in steel metallography seems to be the skill and facility with which these techniques are carried out. *(Reported by G. W. Graves for Chicago.)*

Office of Naval Research and Research and Development

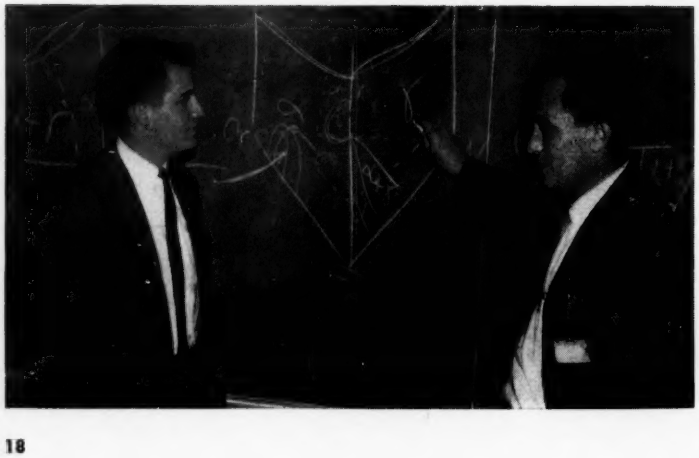
IMPORTANT PHASES OF RESEARCH in which the Navy has participated during the last 1¼ centuries were reviewed in Richmond in a talk entitled "Research and Development With Navy Slants" by Rear Admiral R. Bennett, Chief, Naval Research Laboratory.

Among Navy research firsts were the establishment of the Naval Observatory during the 1830's and the chartering of the ocean currents by Maury. In addition to its contributions to the improvement of methods and equipment for land, sea and air defense, Naval Research has contributed heavily to progress in basic sciences and materials. At the present time, the navy is conducting many large-scale basic research projects.

Adm. Bennett emphasized that present-day technology is constantly demanding new materials. Re-entry conditions for certain space vehicles make it necessary to use materials which will maintain good strength characteristics at approximately 2000° F. while exposed to the oxidizing conditions of the earth's atmosphere. A recent development has indicated that zinc-plated columbium resists oxidation and has the required strength properties.

Materials and design problems are being solved for applications involving equipment used for exploration at the bottom of the earth's oceans and in the farthest reaches of outer space. The "Trieste", the Navy's deep-sea diving laboratory, has been designed and constructed to withstand the extremely heavy pressures of the deepest ocean bottoms. Only the best steels available were used to withstand the extreme pressures involved. Materials and engineering advances of recent years have made operational the supersonic aircraft which fly at record heights. Recently the Navy held the world's record for altitude for manned flight (4FH jet) and deepest

Oak Ridge Gives Educational Course on the Stainless Steels



Lecturing on Stainless Steels at Oak Ridge Were (Top Left) G. P. Smith, With G. M. Slaughter, Who Spoke on Crystal Structures, (Bottom Left) J. V. Cathcart, Who Reviewed Phase Diagrams With R. G. Gilliland, (Top Right) E. E. Stansbury, University of Tennessee, Who Lectured on Physical Metallurgy With T. S. Lundy, and (Bottom) Adolph Lena, Who Covered Production and Fabrication, With W. O. Harms

penetration of the ocean for manned vehicles.

The Navy Department has always recognized the importance and the challenge of man's search for fundamental knowledge about himself and his mysterious universe. The Office of Naval Research was the first and only service organization authorized by Congress (1946) for conducting fundamental research. As a result of this and its outstanding record of research, the Navy receives many suggestions and applications for sponsoring research. These must be screened very carefully. Two criteria used are: What are the future merits to the Navy? and, How good is the individual or organization making the application? The magnitude of this screening operation is indicated by the fact that approximately 1800 contracts were recently in effect.

Adm. Bennett described several basic fields of research which are receiving much attention by O.N.R., among which are studies of surface corrosion and solid state physics. Important advances have been made as a result of these studies. Improved materials and methods of protection in a variety of environments have resulted. Also, miniaturized components and assemblies have been developed. For example, an airborne computor weighing 31 lb. and occupying only 6/10 cu.ft. space has replaced one of World War II vintage which weighed 142 lb. and occupied 7 4/10 cu.ft. space.

Adm. Bennett discussed the importance of the philosophy, or approach, to research. Recently, he said, O.N.R. has found merit in the "interdisciplinary approach", especially in research institutes where the work load and scope are large. This approach involves assigning all types of engineers and scientists to the project. In addition to bringing diversified backgrounds and trainings to work on the projects, this approach is very effective in the development and training of the individuals involved. *(Reported by W. W. Berkey for Richmond.)*

Important Aspects of High-Strength Welding

"HIGH-STRENGTH WELDING" was the subject of a talk given by Dewitt C. Smith, chief metallurgist, Electrode Division, Harnishfeger Corp., at Akron.

Dr. Smith limited his subject to manual arc welding, stating that the welding electrode fills the positions of both a material and a tool. Industry, at one time, had hoped to develop a universal electrode; however, in contrast there are presently some 175 different electrodes offered

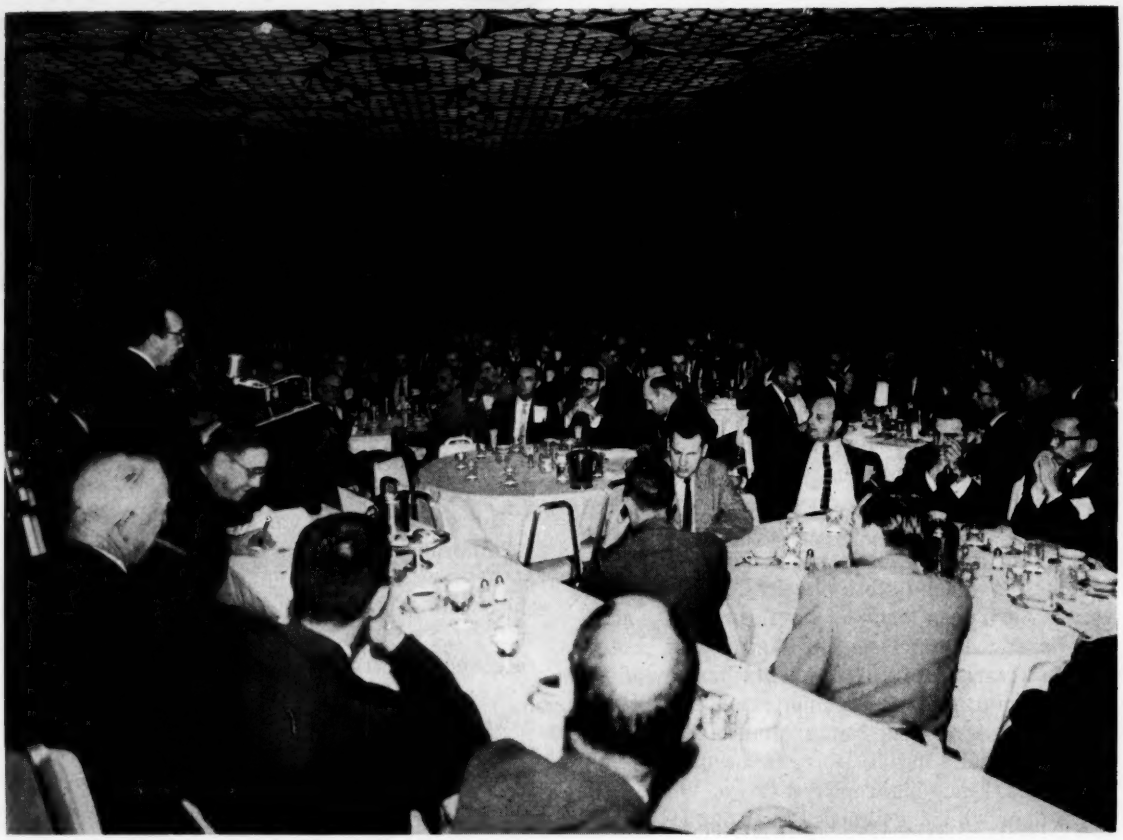
D. C. Smith, Harnischfeger Corp., Is Shown at a Meeting in Akron at Which He Discussed High-Strength Welding

by the Harnischfeger Corp. This is attributed to our age of specialization, wherein it is necessary to design around the steel and application.

The core wire of various electrodes used in welding alloy steels are essentially all the same —the very important difference is achieved in the coating. This coating has the following functions: 1. Stabilize the arc. 2. Control the melting rate and penetration. 3. Gas and slag shielding. 4. Control weld metal composition. 5. Maintenance of weld metal fluidation, allowing separation of gases and nonmetallics. This impressive list reflects the great amount of know-how which must go into the design of electrode coatings.

Dr. Smith then discussed the organic and mineral types of electrode coatings, putting special emphasis on the mineral basic low-hydrogen type. This coating makes it possible to deposit sound weld metal in a structural joint higher in carbon content at lower preheats than possible with conventional coatings. Preheats are necessary to prevent cracking caused by hydrogen diffusing from the weld metal into the adjacent base metal which has been austenitized by the heat of the welding operation. As the temperature returns to normal, the hydrogen solubility decreases, throwing it out of solution. This molecular hydrogen then becomes an internal stress raiser causing embrittlement and cracking.

Moisture in the coatings of these low-hydrogen electrodes causes the cracking problem to become more acute. Sound weldments are possible with a moisture content up to 0.2%; however, a moisture content of 0.3% is very detrimental. The resulting zone in between becomes a questionable area wherein cracking may or may not occur. Various types of electrode coatings are more apt to pick up moisture under equal conditions. Presently, careful control of the coating composition and electrode ovens are used to combat this moisture pick-up problem. *(Reported by C. F. Moewe for Akron.)*



Robert C. Bertossa, General Chairman, Western Metals Conference, Opens Luncheon Meeting at Which More Than 360 Persons Heard Dan A. Kimball Discuss Some U. S. Missiles Problems.

Mettle and Metals Needed for Missiles

METAL AND METTLE are both necessary ingredients in the efforts of the United States to catch and outstrip the U.S.S.R. in the field of rocketry and missilery, according to Dan A. Kimball, president, Aerojet-General Corp., in a luncheon talk before 360 registrants of the Golden Gate Metals Conference.

"We've got to keep improving our metals so we get greater strength with less weight so missile tanks can withstand greater pressures", Kimball stated. "Mettle", he continued, "is a psychological condition we've got to instill into the American people which will give us the 'guts' to go ahead and overtake anybody in the world —which we've got the brains, technology and resources to do."

Indicating confidence in the ability of the United States to assume leadership in space activities, Kimball, a former secretary of the Navy, stated there is a need to cut through governmental red tape and spend considerably more money to achieve this position.

Cites Metal Advances

As an example of progress in engineering materials, Kimball pointed out that in 1955 metals having tensile strengths of 150,000 psi. were the best available. Today production quantities of solid-fuel rocket cases are being made of low-alloy steels heat treated to strength levels of 200,000-210,000 psi.

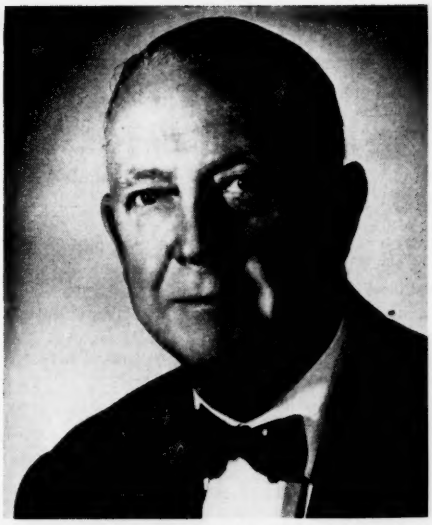
Pointing out that any reduction in weight of

missile case or motor can be translated into increased range or larger payload, the speaker cited a typical problem. "An advanced rocket motor case of modern design will have a mass fraction of slightly less than 0.9 in., he stated. "This means that the ratio of the propellant weight to the total weight is 90%, assuming that we are using a 210,000 psi. steel. To improve the performance of the motor to achieve an increase in the mass fraction of only 0.04, to a value of 0.94 would require a steel with a strength of 425,000 psi. We have reached the point where slight increases in performance can only be achieved by stretching the limits of the available technology almost beyond the point where we can comprehend our ability to do so."

Although steel is most generally used, other materials are now being investigated and used. Among them are beryllium, titanium and various types of composite materials.

Improvements in propellants have brought with them new metals problems. For example, propellants now used have flame temperatures of 5000° F. and are soon expected to develop 6000° F. flame temperatures. An increase up to 7000° F. is predicted for this decade.

Although missile cases present certain difficult materials problems, nozzle parts in missiles are in direct contact with the burning propellant gases. Today we cannot take full advantage of the newer fuels because of a lack of suitable materials for these high-temperature parts. Refractory metals, carbons and certain ceramics are being investigated for use in these areas.



Dan A. Kimball, President, Aerojet-General Corp., Spoke Before a Western Metals Conference Luncheon Meeting on Some Materials Problems in Missiles.

Problems Faced

Citing the problems involved in space travel, Kimball listed the types of environment in which the high-temperature materials must operate. They include: ultra-high flame temperature; steep transient temperature gradients; high heat flux; supersonic gas flow; chemically reactive combustion products; abrasion by high velocity particles; stresses due to pressure, structural loading, temperature and acceleration.

To complicate the problem, the nozzle structure, in addition to being able to withstand the listed conditions, must be as light as possible. At the present time, nozzle components make up over 20% of the total inert parts weight. This must be reduced to meet future operating requirements.

In conclusion, the missile expert told the audience: "The metals industry is an important part of our air-space resources. Progress we make in the future will depend greatly on your research and your achievements".

Magnesium and Lithium (Continued)

purities from steel and its use results in a better ingot. It also has some value in the development of better machining alloys and certain alloys with better working properties.

The undeveloped status of lithium metallurgy in general can be appreciated when it is realized that there are less than one-half dozen references in the literature on four component alloys systems containing lithium. The greatest amount of work has been with binary and ternary systems and but few of these have been thoroughly studied. The very light weight of lithium metal and certain of its chemical characteristics have made it somewhat difficult to accurately investigate its metallurgical properties as an alloying element for steel. This interesting element has a definite future in the metallurgical industry.

Cold Extrusion (Continued)

work where they were previously overlooked. Many of the high-quality alloys formerly needed in all extrusion work are no longer required, in many instances because of advances made in the field. Carbon is the element in alloys which has the greatest influence on the success of a material in cold extrusion work. *(Reported by Walter A. Luce for Dayton.)*

CHAPTER MEETING CALENDAR

Albuquerque	**May 19**		**D. J. McPherson**	Physical Metallurgy of Titanium and Zirconium
Baltimore	**May**	York, Pa.	**Tri-State Meeting**	Washington, Baltimore and York Chapters
Boston	**May 6**	MIT Faculty Club	**Carl Hastings**	New Methods of Nondestructive Testing
Calumet	**May 10**		**R. F. Thompson**	Selection of Metals for Automotive Application
Chicago	**May**			Ladies Night
Chicago-Western	**May**			Ladies Night
Cleveland	**May 2**			Machineability Panel
Columbus	**May 4**	Ann-Ton's Restaurant	**Dorsie C. Harleman**	High Energy (Explosive) Metal Forming
Dayton	**May 26**	Walnut Grove Country Club		Annual Business Meeting and Outing
Delaware Valley	**May 18**		**Frank McKiernan**	The Miracle of the Tin Can
Eastern New York	**May 10**			Art and Science in Silver
Hartford	**May 10**			Plant Visit
Indianapolis	**May 16**		**Glenn A. Fritzlen**	Hard Facing Alloys
Jackson (Michigan)	**May 17**	Engineering Castings Co.		Plant Tour
Kansas City	**May**			Spring Party
Mahoning Valley	**May 17**		**Carl H. Samans**	Metals Make Gasoline Possible
Milwaukee	**May 6**			Annual Party
Montreal	**May 2**		**P. E. Cavanagh**	Panel Discussion
Muncie	**May 10**		**D. E. Martin**	Fatigue Testing
New Haven	**May 19**	Colonial House		Missiles
New Jersey	**May 16**	Hotel Essex House	**Cyril N. Hoyler**	Electronics in Action
New York	**May 2**		**D. E. Davenport**	Response of Metals to Explosive Impact
North Texas	**May 5**			National Officers Night
Oak Ridge	**May 21**			Annual Ladies Night
Ontario	**May 6**	Prince George Hotel	**M. Cohen**	Corrosion and Its Prevention
Penn State	**May 14**		**Manley E. Brooks**	Development of the Magnesium Industry in the U.S.
Philadelphia	**May 12**	Engineers Club	**J. L. Meyer**	Adventures in Metallurgy
Phoenix	**May 17**			Beryllium and Beryllium Alloys
Purdue	**May 17**	Lafayette	**Francis G. Tatnall**	Philosophy of Measurement
Rhode Island	**May 13**	Sheraton - Biltmore Hotel		Northeast Regional Conference
Richmond	**May 10**			Ladies Night
Rochester	**May 9**			Annual Meeting
Rockford	**May 25**	Hotel Faust	**P. J. Zrimsek**	Patent Law
Saginaw Valley	**May 7**	Rolling Green Country Club		Spring Dinner-Dance
St. Louis	**May 19**		**Walter Crafts**	Facing the Productivity Challenge: Men and Metals of the Next Decade
Southern Tier	**May 2**		**C. H. Samans**	National Officers Night
Syracuse	**May 20**	Onodaga Hotel	**W. A. Pennington**	Mild Steel in Corrosion Service
Texas	**May 3**		**Walter Crafts**	Facing the Productivity Challenge: Men and Metals of the Next Decade
Tulsa	**May 3**		**George J. Sloan**	Fascinating Facts About Diamonds
Washington	**May 16**	All-States Restaurant	**Walter Crafts**	Facing the Productivity Challenge: Men and Metals of the Next Decade
West Michigan	**May 16**	Scotties Restaurant	**C. H. Samans**	Metals Make Gasoline Possible
Wilmington	**May 11**	Fabians Restaurant	**E. M. Mahla**	Metallurgy of Columbium
Worcester	**May 11**	Stockholm Restaurant		Ladies Night
York	**May 14**	York		Tri-State Meeting

Notice anything new about this month's *Metals Review?* We think the changes in editorial format and design will make this publication easier to read as well as more attractive.

In addition, a new printer and a new printing schedule permit two important improvements to be made:

1. This issue should be in the hands of all A.S.M. members by the 15th of the month of publication. The earlier publication date will be maintained and, if possible, be improved upon in the future.
2. Provisions have been made to carry more late news of chapters, national activities and metalworking in general.

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Operated on a no-charge basis for A.S.M. members in good standing. Ads are limited to 50 words and only one insertion of any one ad. Address answers to: Box No., American Society for Metals, Metals Park, Novelty, Ohio, unless otherwise stated.

POSITIONS OPEN

Midwest

PROFESSORSHIPS: Metallurgical Engineering. Positions open in benefication, extractive and physical metallurgy. Graduate and undergraduate teaching with ample research opportunity. Advanced degree essential. Immediate need for man to teach X-rays and to initiate course in electron microscopy. Rank dependent upon experience. Contact: R. L. Smith, Dept. of Metallurgical Engineering, Michigan College of Mining and Technology, Houghton, Mich.

RESEARCH METALLURGIST: Ph.D. degree or equivalent in experience and interested in fundamental problems in metal fabrication and the physical and mechanical properties of metals, cermets, etc. Excellent research facilities and assistants are available for development of a research program. Opportunity for part-time teaching if desired. Send résumé to: Institute for Atomic Research, Ames Laboratory, U.S. Atomic Energy Commission, Box 14-A, Station A, Ames, Iowa.

METALLURGICAL ENGINEER: With metallurgical degree and three or more years experience in general plant work to assume chief responsibility for specifying materials and heat treatment in established company manufacturing heavy machinery. Box 4-5.

TEACHING AND RESEARCH ASSISTANTSHIPS: For advanced degree students in metallurgy. Courses and research facilities are available for kinetics, mechanical metallurgy, physical metallurgy, physics of solids, thermodynamics, X-ray diffraction. Applicants with undergraduate degrees in science or engineering will be considered. Write: Dept. of Metallurgy and Materials Science, The Technological Institute, Northwestern University, Evanston, Ill.

RESEARCH METALLURGIST: Opportunity in research laboratory of leading steel castings producer. Applicant must have B.S. in metallurgy or metallurgical engineering and some experience with steel. Work involves studies of melting, alloying and heat treatment of steel. To age 35. Salary commensurate with experience and ability. Write: John A. Rassenfoss, Manager, Manufacturing Research Laboratory, American Steel Foundries, 3761 Canal St., East Chicago, Ind.

East

METALLURGICAL ENGINEER: Recent graduates for development positions with producer of ferrous, nonferrous and reactive metals specialty tubing. Positions in nondestructive testing and alloy development. Modern laboratory of multi-plant company, suburban location. Box 4-10.

West

WELDING ENGINEER: B.S. degree in welding metallurgy or metallurgical engineering. Position involves research and development in the field of joining with special emphasis on fusion and resistance welding. Work will deal with stainless steels, heat resistant superalloys and refractory metals for application to guided missiles and spacecrafts. Aptitude for research and ability to write reports essential. Salary commensurate with experience. Location in Southern California. Box 4-60.

NONDESTRUCTIVE TEST ENGINEER: B.S. degree in engineering. Position involves research and development with emphasis in ultrasonics and eddy-current methods of testing for application to guided missiles and spacecrafts. Aptitude for research and ability to write reports essential. Salary commensurate with experience. Location in Southern California. Box 4-65.

SENIOR METALLURGISTS: To plan, direct, carry out materials research and development in the nuclear field. Opportunities exist for both applied and basic work in a new laboratory. Currently in progress are programs in thermal stress fatigue, alloy development, high-temperature properties, fuel element development, ceramic coating techniques and properties. An advanced degree and/or experience in the nuclear field would be desirable. Send résumé to: Dean Y. Townsend, Advanced Technology Laboratories, Division of American-Standard, 369 Whisman Rd., Mountain View, Calif.

POSITIONS WANTED

METALLURGICAL ENGINEER: Desires supervisory position. B.S. degree, age 33, married, family. Nine years experience with leading specialty steel producer. Fully acquainted with bar and sheet products of stainless and alloy steels. Experience includes production quality control, claim investigation, customer contact, laboratory supervision. Box 4-15.

METALLURGICAL ENGINEER: B.S. degree, age 29, family. Four years diversified experience in aircraft, rocket and space flight materials applications. Will relocate. Résumé on request. Box 4-20.

METALLURGICAL ENGINEER: M.S. degree, age 28, single. Experience in brass tube mill, quality control, extrusion, and background in many phases of steel processing. Speaks three languages. Desires interesting position in western states or abroad. Consider all fields of metallurgy. Box 4-25.

METALLURGIST: Age 34. Weld testing laboratory supervisor. Technical service for salt bath heat treating including hardening, carburizing, austempering, etc. Materials and process liaison with engineering and production for aircraft accessories. Stainless, low alloy, aluminum, nickel, cobalt alloys involved. Processes included chromium, cadmium plating, nitriding, brazing and hard anodizing. Résumé available. Box 4-30.

METALLURGIST: Married, excellent health, 24 years experience. Metallurgical and mechanical development of special materials and fabricating techniques for gas turbine engine parts, atomic reactors and rocket components, and many others. Extensive experience in customer and vendor contact and administrative duties. Seeks challenging position in similar capacity. Location not a factor. Box 4-35.

METALLURGIST: Age 40, wants to assume the responsibilities of a position in keeping with a minimum salary of $15,000. Familiar with cast ferrous materials from gray iron to stainless steel through activity in applied research and development. Background includes history of effectively working with production, quality control, sales and customer personnel. Box 4-40.

Metallurgists—Met. Engineers—Chemical Engineers.
Present expansion program in both research and production provides openings for above individuals with experience in one or more of the following: electric furnace operation—either open or submerged arc; smelting, melting and refining operations in either ferroalloys or steel. Excellent opportunities for professional growth and advancement. Generous benefits. Salaries open. All replies held in strictest confidence. Send complete resume to:
Mr. R. T. Howard, Technical Director, Chromium Mining and Smelting Corporation, 13550 So. Indiana Ave., Chicago 27, Ill.

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Unique opportunity to *establish* and *head* a new Metallurgical Laboratory for research and development in the field of high temperature materials for advanced flight propulsion systems.

This laboratory will be located in southern Florida at the new research and development facility of a Company world-renowned in the aircraft and missile field.

A PhD in Metallurgy or Metallurgical Engineering and experience in research and basic development are required. Salary open.

Send detailed confidential résumé to:

Box 4-105, Metals Review

The 15th METALLOGRAPHIC EXHIBIT

Philadelphia, October 17 to 21, 1960

All metallographers—
everywhere—
are cordially invited to
display their best work.

RULES FOR ENTRANTS

Exhibitors do not need to be members of the American Society for Metals.

Work which has appeared in previous metallographic exhibits held by the American Society for Metals is unacceptable.

Photographic prints should be mounted on stiff cardboard, extending no more than 3 in. beyond edge of print in any direction; maximum dimensions 14 by 18 in. (35 by 45 cm.) Heavy, solid frames are unacceptable.

Entries should carry a label on the *face of the mount* giving:

Classification of entry.

Material, etchant, magnification and other desirable data.

A brief statement (if desired) calling attention to any unusual aspect of the entry.

The name, company affiliation and postal address of the exhibitor should be placed on the *back of the mount* together with a request for return of the exhibit if so desired.

Entrants living outside the United States should send their micros by first-class letter mail endorsed "Photo for Exhibition — No Commercial Value — May Be Opened for Customs Inspection".

Exhibits must be delivered before Oct. 1, 1960, either by prepaid express, registered parcel post or first-class letter mail, addressed:

Metallographic Exhibit
American Society for Metals
Metals Park
Novelty, Ohio, U. S. A.

CLASSIFICATION OF MICROS

Class 1. Irons and steels, cast and wrought
Class 2. Stainless steels and heat resisting alloys
Class 3. Aluminum, magnesium, beryllium, titanium and their alloys
Class 4. Copper, nickel, zinc, lead and their alloys
Class 5. Uranium, plutonium, thorium, zirconium and reactor fuel and control elements
Class 6. Metals and alloys not otherwise classified
Class 7. Series showing transitions or changes during processing
Class 8. Welds and other joining methods
Class 9. Surface coatings and surface phenomena
Class 10. Slags, inclusions, refractories, cermets and aggregates
Class 11. Electron micrographs using replicas
Class 12. Electron micrographs (transmission)
Class 13. Color prints in any of the above classes
Class 14. Results by unconventional technique

AWARDS AND OTHER INFORMATION

A committee of judges will be appointed by the Metal Congress management which will award a First Prize (a medal and blue ribbon) to the best in each classification. Honorable Mentions will also be awarded (with appropriate medals) to other photographs which in the opinion of the judges closely approach the winner in excellence. A Grand Prize, in the form of an engrossed certificate and a money award of $500 from the Adolph I. Buehler Endowment will also be awarded the exhibitor whose work is judged best in the show, and his exhibit shall become the property of the American Society for Metals for preservation and display in the Society's national headquarters.

All prize-winning photographs will be retained by the Society for one year and placed in a traveling exhibit to the various Chapters.

42nd NATIONAL METAL CONGRESS & EXPOSITION

Philadelphia Trade & Convention Center——————Oct. 17 to 21, 1960

THREE OPENINGS in METALLURGICAL R & D

Exceptional career opportunities for three men in metallurgical research and development with broad interests in these areas:

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Specifically, we are seeking:

PHYSICAL METALLURGIST. With Ph.D., two to five years experience. Will be responsible for several projects and direct others. Particular interest in alloy development and heat transfer.

FOUNDRY METALLURGIST. With B.S. or M.S. Recent graduate or up to five years of experience.

METALLURGIST. With B.S. Recent graduate or up to three years of experience.

All three will work on a broad range of projects associated with the metallurgical needs of glass, paper and plastics manufacturing.

THOSE WHO JOIN US will work at the Owens-Illinois Technical Center in Toledo. Toledo is a community of 350,000 with many delightful residential sections, fine schools and a well-rated university. Cultural facilities include a renowned art museum and zoo. The community has excellent recreational facilities. You can drive via turnpike to Chicago or Pittsburgh in 4½ hours, and to Ann Arbor (University of Michigan) or Detroit by expressway in one hour.

WHO WE ARE. Owens-Illinois manufactures Duraglas containers; Libbey table glassware, Kimble scientific and electronic glassware, and construction glass products. We are one of the leading manufacturers of corrugated paperboard and boxes, closures and plastic containers. We have 57 plants and mills, and more than 32,000 employees.

For interview, contact:

RAY S. RICHARDS
Chief Metallurgist
Owens-Illinois Technical Center
1700 N. Westwood, Toledo 7, Ohio

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STRESS ANALYST AND METALS ENGINEER: M.S. degree, ORSORT graduate, age 36. Ten years experience in theoretical and experimental stress analysis and mechanical metallurgy in both nuclear and metals industries. Experience in conceptual design, development and research, with recent emphasis on designs for high-temperature applications. Desires challenging position in applied research. East preferred. Box 4-45.

PHYSICAL METALLURGIST: Ph.D. degree, age 36, family. Eight years experience in industrial research, contract research and as a member of university faculty. Publications. Nuclear experience. Position desired in industrial research organization or on university faculty. Location not a factor. Résumé on request. Box 4-50.

METALLURGICAL ENGINEER: M.S. degree, 15 years experience in process, development and research metallurgy. Teaching and administrative experience. Desires challenging position on the executive level. Box 4-55.

RESEARCH METALLURGIST: M.S. degree, age 40, family. Eleven years experience includes alloy development of stainless steels and some nickel-base alloys, plus limited studies of various metallurgical problems. Has nine published papers. Four patents granted, four pending. Will locate anywhere in U.S. Box 4-70.

MANAGEMENT LEVEL ENGINEER: Age 36, B.S., M.S. degrees in metallurgical engineering. Qualified administrator. Experienced as director of engineering and manufacturing in specialized foundry, powdered metallurgy, fabrication, heat treatment; magnetic alloys and refractory metals. Desires management position with progressive company. Three years in South America. Location immaterial. Box 4-75.

METALLURGICAL ENGINEER: B.S. degree, age 34, veteran, family. Three and one-half years research on wrought and cast stainless steels and high-temperature alloys. Six years experience as melting supervisor and metallurgist in high production gray iron foundries. Desires responsible position with an industrial concern which will utilize background. Résumé on request. Box 4-80.

Large corporation with diversified activities has an exceptional position available for:

Chief of Materials Development

Who is qualified to lead several groups in development work on materials for high temperature applications, involving metals, ceramics and plastics.

Preferably Ph.D with ten years research and development experience in high temperature materials plus good administrative abilities.

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OPPORTUNITIES IN IBM RESEARCH

ENGINEERING METALLURGY

The IBM Research Center in Westchester County, New York, has an excellent opportunity for either a metallurgist or an engineer with a good background in the mechanical behavior of materials.

The assignment, involving both basic and applied problems, will be concerned with material characteristics such as creep and fatigue. Representative examples of projects will include studying the effect of fretting and stress localization on fatigue life, or investigating the creep of materials under conditions of multiaxial stress.

QUALIFICATIONS:

Advanced degree in Metallurgy or Engineering. In addition, you should be familiar with the applications of metals in industry and be capable of formulating a research program related to the needs of an engineering organization.

You will be working with people who are outstanding in their respective fields. You will be eligible for many liberal employee benefits, including a comprehensive education program. This is a unique opportunity to join a company engaged in interesting and challenging research.

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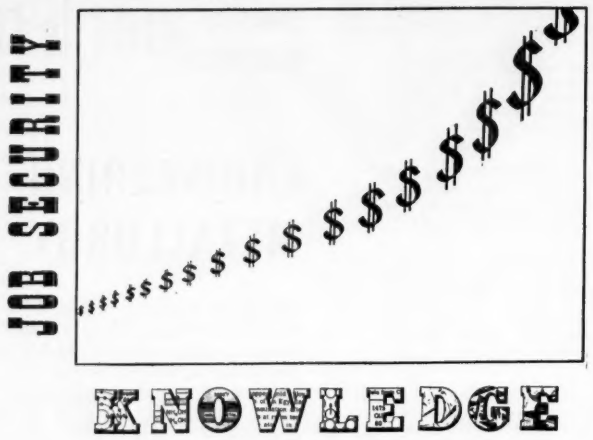

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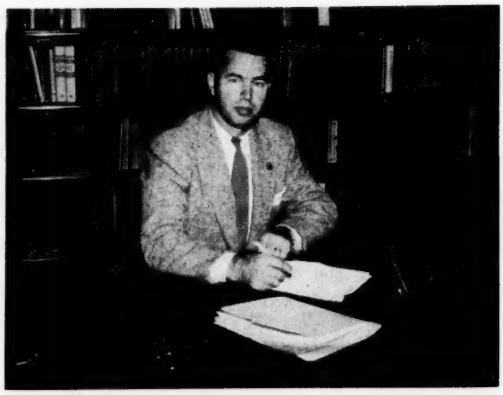

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Interesting position open in the Metallurgy Department of a large industrial materials research laboratory for a metallurgical engineer with 3-5 years experience, preferably in high-temperature work, to apply metallurgical principles to the development of cermet materials. Replies held in confidence.

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Box 4-120, Metals Review

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SUPERVISORY POWDER METALLURGIST —To organize and coordinate an integrated research program covering the preparation and compaction of metal powders. Must have a minimum of five years experience in a related field.

PROJECT ENGINEER—To carry out specifically assigned projects involved in a beryllium powder metallurgy program. Must have a minimum of two years experience in a related field.

SENIOR TECHNICIAN—To perform various duties within the powder metallurgy section pertaining to attritioning, die compaction, furnace operation and product evaluation. This is a responsible position requiring a person with a minimum of five years experience in powder metallurgy operations.

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Fuel Fabrication. Development of equipment and processes for fabrication and assembly of fuel elements. Develop melting, alloying, forming, welding and joining processes for new alloys and ceramic materials.

Corrosion Research. Corrosion and heat transfer research on new materials and advanced liquid metals at elevated temperatures.

Hot Cells. Design and development of hot cell equipment and processes. Remote handling of radioactive materials, especially metallurgical and physical testing.

Irradiation Experimentation. Design and conduct irradiation experiments on reactor fuels over wide range of radiation and temperature conditions, including simulation of conditions expected in full scale power reactors. Development of equipment and techniques for post-irradiation testing and evaluation of these experiments.

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Continuing growth of the J&L research and development program has created a number of openings for professional personnel, holding Ph.D., M.S., or B.S. degrees in metallurgy or a related scientific field. Projects underway or in prospect cover a diversity of subjects in physical and process metallurgy, all of course, related to the production of carbon and stainless steels, and all company supported. Because of this diversity, it is almost always possible to accommodate individual interests.

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H. W. L. PHILLIPS
(Institute of Metals Monograph No. 25)

90 P., numerous diagrams.
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This monograph consists of annotated equilibrium diagrams of the aluminium-rich parts of 20 binary and 12 ternary alloy systems (Al-Ag, Al-B, Al-Be, Al-Bi, Al-Co, Al-Cr, Al-Cu, Al-Fe, Al-Mg, Al-Mn, Al-Na, Al-Ni, Al-Pb, Al-Sb, Al-Si, Al-Sn, Al-Ti, Al-W, Al-Zn, Al-Zr; Al-Cu-Fe, Al-Cu-Mg, Al-Cu-Mn, Al-Cu-Si, Al-Fe-Mg, Al-Fe-Mn, Al-Fe-Ni, Al-Fe-Si, Al-Mg-Si, Al-Mg-Zn, Al-Mn-Si and Al-Ni-Si).

In each case the published literature has been carefully assessed, and what are regarded as the most reliable results are presented in a series of diagrams with critical notes and references.

The author has been associated for many years with the Research Laboratories of The British Aluminium Co., Ltd., and has himself been responsible for a good deal of work on the constitution of aluminium alloys.

The monograph is an indispensable reference book for all concerned with aluminium alloys.

Copies may be obtained through booksellers or direct from:

THE INSTITUTE OF METALS
17 Belgrave Square, London, S.W.1, England

RESEARCH METALLURGISTS MATERIALS ENGINEERS

Advanced Technology Laboratories currently can offer a number of senior positions in connection with materials research and development programs in the nuclear field.

Opportunities exist for metallurgists to carry out both basic and applied research in connection with fuel element development programs. A number of interesting investigations are currently in progress covering the fields of mechanical metallurgy, alloy development, and ceramic fabrication techniques. Materials engineers are needed for several advanced reactor design projects.

Send resume, in confidence, to: Dean W. Townsend, American-Standard, Advanced Technology Laboratories, 369 Whisman Road, Mountain View, California.

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BERNARD S. LEMENT HAS WRITTEN FOR YOU . . .

DISTORTION IN TOOL STEELS

A NEW BOOK PUBLISHED BY AMERICAN SOCIETY FOR METALS

Distortion in Tool Steels is a practical, easy-to-read book exploring the size and shape changes in tool steels which occur during and after processing.

Readers will benefit greatly from the experience of its author. Dr. Lement's background includes both theoretical and practical work in this field and in this book he has sorted the most useful data yet assembled on this expensive problem to industry. His comprehensive knowledge has resulted in this first-of-its-kind book for metals and materials engineers, tool engineers, designers, heat treaters, machinists, mechanical engineers and inspectors.

Dr. Lement places particular emphasis on methods of heat treatment that are necessary for precise dimensional control. The problems encountered in the production of tool steel parts with extreme tolerances (cutting tools, dies, gages, ball bearings, valves, etc.) are treated in detail.

Also, how to prevent significant changes in finish dimensions during storage or under normal service conditions is discussed. How to minimize or eliminate costly finish machining operations by scientific dimensional control is thoroughly explored.

Tables, drawings, charts and graphs highlight the book's eight chapters:

1. CAUSES OF DISTORTION
2. MEASUREMENT OF DIMENSIONAL CHANGES
3. CALCULATION OF SIZE CHANGES
4. CONTROL OF DISTORTION
5. HARDENING
6. COLD TREATING
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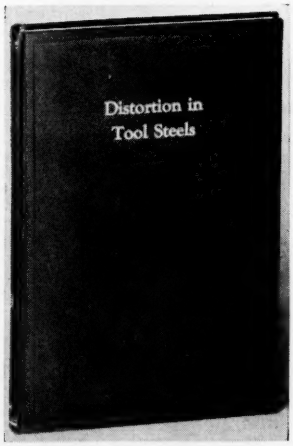

If you are directly or indirectly related to the manufacture of tool steels or tool steel parts, *Distortion in Tool Steels* is a work of great importance. Dr. Lement writes to the men responsible for tool steel performance. His book represents an opportunity to become fully informed on size and shape changes in tool steels. Order your copy today.

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Distortion in Tool Steels—173 P.—8 chapters—illustrated—red cloth cover—6" x 9"—published by American Society for Metals—written by Dr. Bernard S. Lement—$10.00 per copy.

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4. Nuclear Materials and Equipment
5. Tool Materials, Cutting-Off and Forming Equipment
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7. Cleaning and Finishing Equipment and Supplies
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10. Production and Casting Equipment and Supplies
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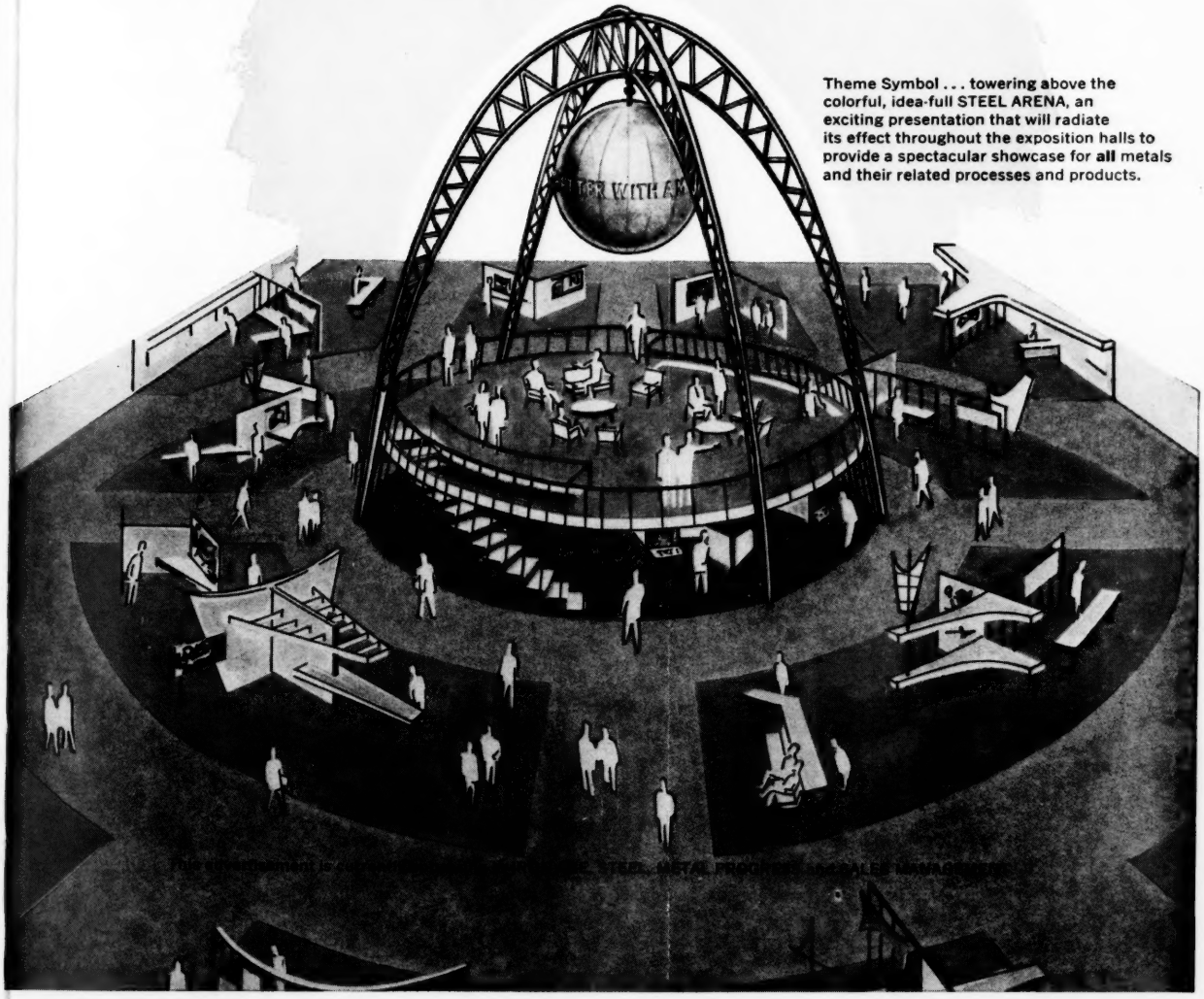

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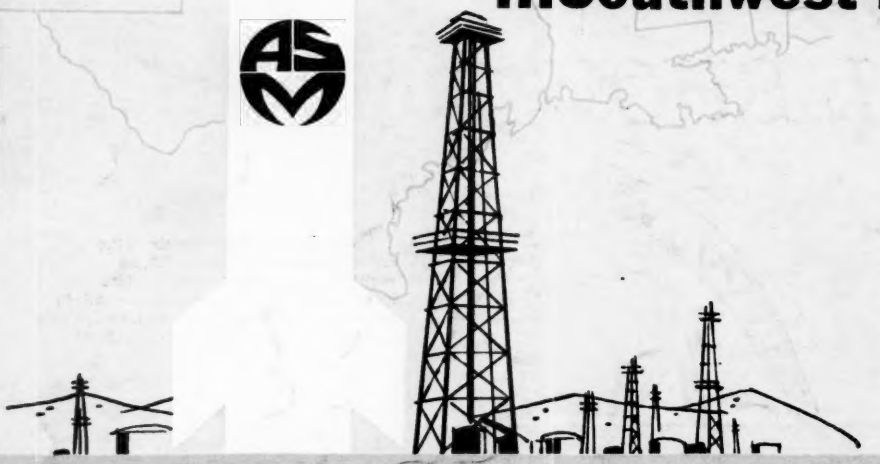

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